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(54) Cutting mechanism

(57) An ultrasonic cutting device comprising:

a) an ultrasonic vibrating means which, in operation, generates ultrasonic vibration in a longitudinal direction,

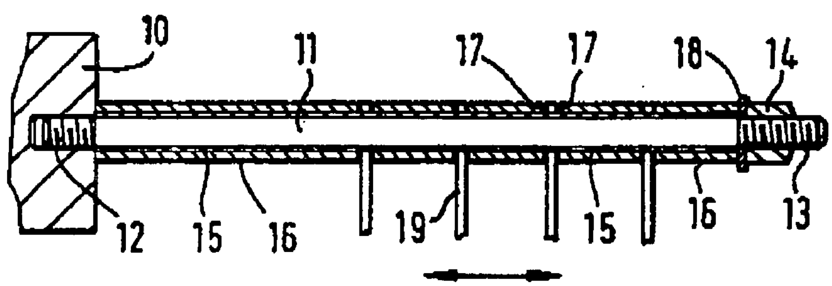
b) a solid horn whose length is a multiple of half-wavelengths connected to and extending away from the vibrating means in the longitudinal direction of the ultrasonic vibrations,

c) a plurality of tubular spacer horns each of which has a length of substantially one half-wavelength having vibrating faces arranged end to end to surround the solid horn,

d) at least one cutting blade fixed between the vibrating end faces of a pair of adjacent tubular spacer horns, the blade lying in a plane extending transversely to the longitudinal axis of vibrations, and

e) clamping means for the spacer horns positioned at the end of the solid horn remote from the vibrating means.

FIG.2.



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Description

This invention is concerned with improvements relating to cutting, particularly by a method involving the use of high frequency (ultrasonic) vibration devices.

The conventional method of ultrasonic cutting involves the use of a cutting blade which is mounted on an ultrasonic vibrating device with the blade lying in a plane containing the longitudinal axis of vibrations, and moving the blade through the article to be cut in said plane.

Difficulty is experienced using conventional methods in that the depth of cut which is attainable is limited. For this reason ultrasonic cutting has in general been limited to thin articles, such as paper, cloth and thin plastic sheets. A significant problem exists in cutting blocks of substantial depth, and/or in providing a number of parallel cuts simultaneously.

Difficulty is also experienced in cutting materials which are brittle or friable, e.g. honeycomb or crystalline materials which may shatter if dropped.

In our co-pending EU-A-89109488.0 there is described and claimed a method and apparatus for cutting an article involving mounting a cutting blade on an ultrasonic vibrating device in a manner such that the blade lies in a plane extending transverse (preferably at right angles) to the longitudinal axis of vibrations, and moving said blade in said plane through said article.

In this manner the blade moves back and forth transverse to the plane in which it moves through the article, effecting a removal of the material of the article along the line of cut. The blade vibrates in a complex vibrational mode determined by the blade dimensions.

The vibrating device comprises basically a vibrating means in the form of a horn, usually rod shaped, the front face of which is caused to vibrate at ultrasonic frequency by a source of ultrasonic power e.g. a transducer producing sinusoidal motion secured to the rear of the horn either directly or indirectly through a booster device. The ultrasonic horn generates the ultrasonic vibrations in a direction having a longitudinal axis in which the maximum vibration occurs at each end i.e. the front face and the rear face which form the antinodes at a quarter wavelength from a node which is stationary in space and which is positioned at a point half way between the antinodes. Usually, the length of an ultrasonic horn is well defined as half the wavelength.

In one embodiment of the invention of EU-A-89109488.0, the vibrating device comprises one or more support members secured to the ultrasonic horn, which are vibrated by the ultrasonic horn, each support member supporting a plurality of blades each blade secured at an antionode where they are caused to vibrate. These support members are also known as spacer horns because the blades are spaced along them.

Each support member is made of a number of separate solid pieces, preferably rod-shaped, each half a wavelength in length which are joined together end to end. The conventional method of joining the support members is by means of grub screws, which enables the two end faces to be very tightly fastened by applying a rotational torque. The blades are fixed between the end faces which form the antinodes where maximum vibrations occurs.

There are a number of disadvantages of the above method of fixing the blades:

a) Since each support member is made of a plurality of pieces, there are possible stress concentration failure initiation points,

b) Each support member is ultrasonically complex owing to the plurality of pieces having spanner flat or holes, usually necessary to enable the use of a spanner for tightening the grub screws,

c) The blades are subjected to rotational torque on fastening and unfastening, and

d) The replacement of blades requires each pair of end faces to be unfastened one by one.

We have now devised an improved device which overcomes the above disadvantages.

Accordingly, the present invention provides an ultrasonic cutting device comprising:

a) an ultrasonic vibrating means which, in operation, generates ultrasonic vibration in a longitudinal direction,

b) a solid horn whose length is a multiple of half-wavelengths connected to and extending away from the vibrating means in the longitudinal direction of the ultrasonic vibrations,

c) a plurality of tubular spacer horns each of which has a length of substantially one half-wavelength having vibrating faces arranged end to end to surround the solid horn,

d) at least one cutting blade fixed between the vibrating end faces of a pair of adjacent tubular spacer horns, the blade lying in a plane extending transversely to the longitudinal axis of vibrations, and

e) clamping means for the spacer horns positioned at the end of the solid horn remote from the vibrating means.

The ultrasonic vibrating means to which the solid horn is connected is conveniently in the form of a horn, hereinafter referred to as a mother horn which is caused to vibrate at ultrasonic frequency by a source of ultrasonic power e.g. a transducer. The transducer is secured to one end of the mother horn (the opposite

end to that which is connected to the solid horn) either directly or indirectly. When the mother horn is secured to the transducer indirectly, this may be through a booster device which adds "gain" or "increased amplitude of vibration" or through a rod-shaped ultrasonic horn which has a vibrating face at each end one of which is secured to the transducer.

The length of the solid horn may be up to, for example, 20 half wavelengths but for practical purposes the length is usually from 3 to 12 and preferably from 5 to 10 half wavelengths.

The solid horn may conveniently be connected to the mother horn by conventional means such as a grub screw, a threaded end with shoulder or by welding. The solid horn is preferably made of one piece although, optionally, it may be made of a plurality of pieces each half a wavelength in length screwed together by grub screws.

The tubular spacer horns are adapted to slide along the solid horn. The length of each tubular spacer horn is adapted to slightly more or less than half a wavelength to allow for blade thickness and blade material. The tubular spacer horns may be provided with a lip or washer segment at their vibrating faces in order to apply uniform pressure to the blade and adjacent horn.

The mother horn, the solid horns and the tubular spacer horns are preferably made of high fatigue strength aluminium or titanium alloys.

The blades are conveniently made of hard, tough or flexible materials e.g. steel, graphite impregnated steel, tempered high tensile steel, flexible ceramics such as zirconium types or fibre reinforced composites. They could be coated with non-stick and/or hard wearing non-abrasive coatings such as chrome, polytetrafluoroethylene or flexible ceramics or by other surface- hardening treatments. The cutting edge of the blade may be spark-eroded or otherwise cut to produce a hollow edge.

The clamping means may be provided by one of a variety of options. For example, the end of the solid horn remote from the vibrating means may be threaded and a nut may be provided for screwing onto the threaded end. Preferably the length of the nut should be one half a wavelength or such that the whole clamped assembly vibrates at the required frequency. In another method, the clamping means may be provided by a hydraulic or pneumatic cylinder which is adapted to apply force to the end of the tubular spacer horn remote from the vibrating means.

The tubular spacer horns may, if desired, be shaped by conventional means to give amplitude gain.

Means may be provided to avoid friction welding between the tubular spacer horns and the solid horn. One possibility is to provide either the solid horn or the tubular spacer with a nodal flange bearing. Alternatively, a bearing tube may be fitted onto the solid horn within the tubular spacer horns in order to isolate friction variation effects. The bearing tube is advantageously made of fibre or plastics bearing material e.g tufnol. If desired, passages may be provided between the bearing tube and the solid horn and between the bearing tube and the tubular spacer horns for blowing or pumping cooling air or fluid through the cavities.

Advantageously, there may be two solid horns connected to the ultrasonic vibrating means, parallel to one another so that each blade may be supported by the adjacent vibrating faces of the two tubular spacer horns surrounding the solid horns, each blade advantageously being secured at each of its respective ends. Such a device with a double-drive has more cutting power then a single-drive device where only one solid horn is secured to the ultrasonic vibrating means. In this embodiment one or more further pairs of parallel solid horns each supporting one or more blades, may advantageously be secured to the ultrasonic vibrating means.

The blades may be wide, narrow, thin or they may be wires. They may be round, triangular or roughly square in shape but preferably rectangular e.g. from 10 to 100 mm long and from 1 to 22 mm wide. When the blades are roughly square or rectangular in shape, they are advantageously profiled so that they are narrower along a portion of their lengths than at their ends. For example, from 40% to 90% and preferably from 50% to 70% of their length between the ends is narrower and the width may be up to 60% less than at the ends. The thickness of the blades may be from 0.25 to 1.5 mm and more usually from 0.5 to 1.35 mm, especially from 0.85 to 1.2 mm. The blade may be provided with an aperture in its body, preferably in the middle to enable it to slide along the solid horn whereas a blade which is driven at each end may be provided with an aperture at each end. The blades are placed in position by sliding tubular spacer horns and blades successively along the solid horn so that a blade is positioned between adjacent faces of two tubular spacer horns. Advantageously, the aperture may be cut away to give a "horseshoe shape" to enable easy disassembly and blade replacement without removing the tubular spacer horns. It should be understood that the vibrating end faces of the tubular spacer horns are positioned substantially at the antinodes.

The antinode is the crest of a sinusoidal oscillation, hence, as used herein, an antinode shall be understood as meaning one quarter wavelength ± 10% from the node, the node being a stationary point where there is no vibration, preferably one quarter wavelength ± 5%, more preferably ± 2%, even more preferably ± 1% from the node and most preferably at the true antinodal point i.e. one quarter wavelength from the node.

The present invention also provides a method of cutting an article by means of an ultrasonic cutting device as hereinbefore defined according to the present invention which comprises passing the cutting blade through the said article.

The movement of the blade relating to the article to be cut may, if desired, be achieved by moving the article through the blade. However, it is also possible to move the blade through the article to be cut.

The frequency used may be within the audio range from 5 to 15 KHz but is preferably between 15 and 100 KHz, especially from 20 to 40 KHz.

The present invention has the following advantages:

1) The blades are not subject to a rotational torque.

2) The blades can be individually and quickly replaced by slackening the end nuts, or releasing the alternative clamping means.

3) The tubular spacer horns can be ultrasonically simple without spanner flat or holes.

4) The solid horn has no studs as it is a one piece device, hence no stress concentration failure initiation point.

The present invention will now be further illustrated by way of example only with reference to the accompanying drawings in which

Figure 1 represents a diagrammatic side plan view of a cutting device of the present invention,

Figure 2 represents a diagrammatic side sectional view of a cutting device of the present invention, and

Figure 3 is a plan view of a blade.

Referring to the drawings, the cutting device comprises a mother horn having a front face 10a, a solid horn 11 having a length of 6 half wavelengths and made of high strength titanium alloy, one end 12 of which is threaded and screwed into the mother horn, and the other end 13 of which is threaded onto which is screwed a nut 14 having a wavelength of one half wavelength.

Surrounding the solid horn 11 is a bearing tube 15 made of tufnol forming an inner sleeve. Surrounding the bearing tube are six tubular spacer horns 16 made of high strength titanium alloy each having a wavelength of approximately half a wavelength adapted to slide along the bearing tube 15. The ends of adjacent tubular spacer horns are formed with lips 17 and the end of the tubular spacer horn remote from the mother horn 10 and adjacent the nut 14 is formed with a flange 18.

Blades 19 made of steel are clamped between adjacent faces of the tubular spacer horns. Figure 3 shows a blade 19 which is to be driven at both ends which is to be connected at each end to one of two parallel solid horns 11 and where the clamping ends are cut away to give a horseshoe shape 20.

The lips 17 of the tubular spacer horns enable uniform pressure to be applied to the blades and adjacent horn.

To assemble the device, the solid horn 11 is screwed into the mother horn 10 and the bearing tube 15 is then slid over the solid horn. The tubular spacer horns 16 and blades 19 are slid along the bearing tube 15 successively so that the blades 19 are positioned between adjacent faces of the spacer horns 16 held by their clamping rings. The nut 14 is screwed onto the threaded end 13 of the solid horn 11 until the tubular spacer horns 16 clamp the blades 19 tightly.

In operation, a transducer (not shown) produces ultrasonic power causing the front face 10a of the mother horn and the end faces of the tubular spacer horns 16 to vibrate at 20 KHz which cause the blades 19 to vibrate in the direction of the arrows shown in Figures 1 and 2. The device passes downwards through a wafer biscuit supported on a table (not shown) to excavate several cuts simultaneously.

Materials which may be cut by this device include metal, stone, plastics, confectionery, chocolate, food, pharmaceutical, cosmetics, paper and cardboard. The device is particularly useful for brittle or friable materials of any thickness and may be used to cut frozen food products.

Claims

1. An ultrasonic cutting device comprising:

   a) an ultrasonic vibrating means which, in operation, generates ultrasonic vibration in a longitudinal direction,

   b) a solid horn whose length is a multiple of half-wavelengths connected to and extending away from the vibrating means in the longitudinal direction of the ultrasonic vibrations,

   c) a plurality of tubular spacer horns each of which has a length of substantially one half-wavelength having vibrating faces arranged end to end to surround the solid horn,

   d) at least one cutting blade fixed between the vibrating end faces of a pair of adjacent tubular spacer horns, the blade lying in a plane extending transversely to the longitudinal axis of vibrations, and

   e) clamping means for the spacer horns positioned at the end of the solid horn remote from the vibrating means.

2. An ultrasonic cutting device according to claim 1 wherein the length of the solid horn is from 3 to 12 half wavelengths.

3. An ultrasonic cutting device according to claim 1 wherein the tubular spacer horns are adapted to slide along the solid horn.

4. An ultrasonic cutting device according to claim 1 wherein the length of each tubular spacer horn is adapted to slightly more or less than half a wavelength to allow for blade thickness and blade material.

5. An ultrasonic cutting device according to claim 1 wherein the clamping means is provided by a nut for screwing onto the end of the solid horn.

6. An ultrasonic cutting device according to claim 5 wherein the length of the nut is one half a wavelength or such that the whole device vibrates at the required frequency.

7. An ultrasonic cutting device according to claim 1 wherein the clamping means is provided by a hydraulic or pneumatic cylinder adapted to apply force to the end of the tubular spacer horn remote from the vibrating means.

8. An ultrasonic cutting device according to claim 1 wherein means are provided to avoid friction welding between the tubular spacer horns and the solid horn.

9. An ultrasonic cutting device according to claim 8 wherein a bearing tube is fitted between the solid horn and the tubular spacer horns.

10. An ultrasonic cutting device according to claim 9 wherein passages are provided between the bearing tube and the solid horn and between the bearing tube and the tubular spacer horns for blowing or pumping cooling air or fluid through the cavities.

11. An ultrasonic cutting device according to claim 1 wherein there are two solid horns connected to the ultrasonic vibrating means, parallel to one another so that each blade may be supported by the adjacent vibrating faces of the two tubular spacer horns surrounding the solid horns, each blade advantageously being secured at each of its respective ends.

12. A method of cutting an article by means of an ultrasonic cutting device according to claim 1 which comprises passing the cutting blade through the said article.

FIG.1.

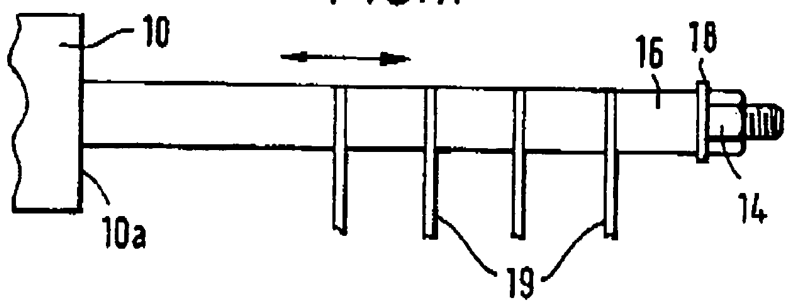

FIG.2.

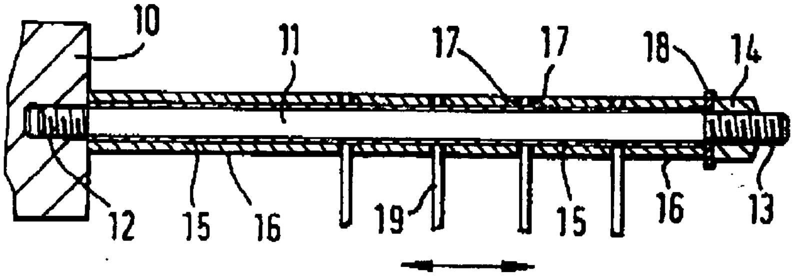

FIG.3.